

Influence of cephalic vein dilation on arteriovenous fistula maturation in patients with small cephalic veins

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Abstract

A substantial limitation of dialysis fistulas is their high primary failure rate due to nonmaturation. Various studies have documented that patients with larger vein diameters exhibit reduced risks for nonmaturation. Nevertheless, some patients have small veins. Few studies have focused on patients with small veins. We hypothesize that sufficient venous dilation contributes to fistula maturation. Therefore, we studied the influence of cephalic vein dilation on fistula maturation in patients with small veins.

Patients with small cephalic veins (diameter <2 mm) undergoing initial arteriovenous fistulae (AVF) operation were included. A total of 72 patients were enrolled in this study. A prospective study was performed, and the patients were followed for 6 weeks after surgery. Preoperative and postoperative duplex ultrasound mapping of veins was performed, and dilation of the cephalic vein was evaluated.

The fistula maturation rate was 44.44%. Multivariate logistic regression analysis revealed a significant relationship between fistula maturation and preoperative cephalic vein dilation. Based on the results of ROC analysis, the fistula maturation rate in patients with vein dilation greater than or equal to the cut-off was 57.14% in the training data set and 54.55% in the testing data set. The independent influencing factors for fistula maturation were used to establish a combined index with logistic regression analysis. The fistula maturation rate in patients with combined indexes greater than or equal to the cut-off was 80.95% in the training data set and 77.78% in the testing data set.

Our results demonstrated that preoperative venous dilation was associated with AVF maturation. For patients with small veins, venous distensibility needs to be carefully assessed before surgery, as it may be a better predictor of AVF maturation than venous diameter.

Abbreviations: AUC = area under the curve, AVF = arteriovenous fistulae, BMI = body mass index, CGN = chronic glomerulonephritis, CIs = confidence intervals, CKD = chronic kidney disease, DBP = diastolic blood pressure, DKD = diabetic kidney disease, DN = diabetic nephropathy, ESRD = end-stage renal disease, K-DOQI = Kidney Disease Outcomes Quality Initiative, ORs = odds ratios, RCAVF = radiocephalic wrist arteriovenous fistula, SBP = systolic blood pressure, SD = standard deviation.

Keywords: arteriovenous fistula, fistula maturation, venous diameter, venous dilation

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1. Introduction

Vascular access is the lifeline of maintenance hemodialysis patients. Primary arteriovenous fistula (AVF) is uniformly recommended as the best permanent vascular access in hemodialysis patients because of its prolonged patency, improved durability, and low risk of infection for fistulas that mature.^[1,2] However, a substantial limitation of dialysis fistulas is their high primary failure rate because of nonmaturation.^[3,4] Various studies have documented that patients with larger vein diameters on preoperative vein mapping are at lower risk for failure of fistula maturation and have increased long-term AVF patency.^[5–10] Some experts suggest a vein diameter of 2.0 mm as adequate for AVF creation.^[5] The preferred minimal vein diameter after dilation for radiocephalic wrist arteriovenous fistula (RCAVF) creation is 2.5 mm.^[11,12] Nevertheless, increasing numbers of patients do not have sufficient vein conditions to undergo AVF surgery given the aging of the population and the increasing incidence of diabetes mellitus.^[13–15] Are any opportunities for AVF anastomosis available for these patients? Do any other factors affect the maturity of AVF? In clinical work, some patients have small but elastic veins, and these expandable vessels may be successfully used in AVF anastomoses. RCAVF is superior to

other types of vascular access for hemodialysis. Patients with small cephalic veins (diameter <2 mm) undergoing their initial permanent hemodialysis access were enrolled in this study. Preoperative and postoperative duplex ultrasound mapping of veins and arteries was performed, and cephalic vein dilation was evaluated. The influence of cephalic vein dilation on fistula maturation was studied to offer a reference for the use of AVF anastomosis in patients with small veins.

2. Patients and methods

2.1. Patients

Patients with end-stage renal disease (ESRD) who underwent placement of new radiocephalic fistulas and who lacked sufficiently large cephalic veins for conventional access (diameter <2.0 mm) were included in the study. The upper limb, shoulder and neck were examined to detect any sign of previous trauma or venous hypertension related to proximal vein obstruction. Pulses were palpated, and Allen tests were performed. The exclusion criteria included previous surgery on the forearm, severe vascular calcification, hypotension (systolic blood pressure <90 mmHg and/or diastolic blood pressure <60 mmHg), advanced heart failure (ejection fraction <30%), the presence of central venous stenosis, or obstruction of the cephalic vein or radial artery before surgery. Patients with a prior failed fistula or graft or a prior tunneled dialysis catheter but who would undergo a new arteriovenous access were not included in the study cohort. Patients with systemic vasculitis and other autoimmune diseases were excluded to avoid the possible effects of these comorbid conditions on the vascular system. All patients underwent fistula surgery with end-to-side vein-artery anastomosis of the cephalic vein and radial artery. Between December 2015 and February 2018, a total of 72 patients were prospectively studied. Baseline demographic indexes were recorded at the time of entry into the study. The patients were followed for 6 weeks after surgery. The local ethics committee approved the study protocol, and all patients provided written informed consent.

2.2. Duplex ultrasound examination

Duplex ultrasound examination was performed using a Philips iU22 ultrasound machine (HI VISION, Hitachi, Japan) with a high-frequency (5–10 MHz) linear probe. Scans were performed preoperatively and at 1, 2, 4, and 6 weeks after surgery by experienced vascular ultrasound technicians and surgeons who performed the vascular access operations. Patients sat upright with arms extended, resting supine on a pillow. The brachial artery volume flow, vessel diameters and anatomical variations were noted. The patients' temperatures were normal. The ambient temperature around the examination room was 77°F.

2.3. Cephalic vein dilation

The diameter of the dilated cephalic vein was measured 3 minutes after the placement of a tourniquet at the 1/3 location of the forearm (the blood flow of the radial artery was not interrupted). Cephalic vein dilation = diameter of the dilated cephalic vein/diameter of the cephalic vein without the tourniquet.

2.4. Surgical technique

All procedures were performed under local anesthesia using the same standardized technique for AVF creation with limited

dissection of the cephalic vein and radial artery. The artery was clamped using an artery clamp, and an end-to-side anastomosis was generated using continuous 7.0 polypropylene sutures. Two experienced vascular surgeons performed the operations.

2.5. Fistula maturity evaluation

Maturation of an AVF depends on flow volume (600 mL/min or greater) and the diameter of the vein used for cannulation (5 mm or greater). Mature fistulas can provide a sufficient cannulation segment length, with an approximate distance of the vein from the surface, can be used for dialysis with 2 needles and can maintain a dialysis machine blood flow rate adequate for optimal dialysis (≥ 200 mL/min).

2.6. Statistical analysis

The data were expressed as the mean with standard deviation (SD) or as the number of patients (percentage), and 95% confidence intervals (CIs) were provided where appropriate. Differences in categorical factors were determined using the Pearson Chi-square test. Differences in continuous values between 2 groups were assessed using the independent-samples *t* test. Multivariate logistic regression analysis was performed to assess the independent association of each parameter with fistula maturation. Resulting adjusted odds ratios (ORs) and 95% CIs were reported. To determine the cut-off of vein dilation, the samples were divided into a training data set and a testing data set according to the uniformly distributed random number method. The training data set accounted for 80% of the samples and the testing data set accounted for 20%. In the training data set, ROC analysis was used to determine the best cut-off of vein dilation using the Youden index maximum method, and the effect of vein dilation cut-off was evaluated in the testing data set. In addition, independent influencing factors for fistula maturation were used to establish a combined index using logistic regression analysis. All tests were two-sided, and differences were considered significant at $P < .05$. All of the statistical analyses were performed using SPSS version 16.0 software (IBM Corporation, Somers, NY).

3. Results

3.1. Patient characteristics

Patient data, including demographic characteristics, hypertension, dialysis, primary disease and vessel diameters, are presented in Table 1. A total of 72 patients were enrolled in this study. Of these, 26 (36.11%) were males, and 46 (63.89%) were females. The average age was 48.33 ± 13.94 years, and the mean body mass index (BMI) was 21.91 ± 2.60 kg/m². The differences in age and BMI between gender were significant ($P < .05$). Male patients had a significantly higher proportion of diabetic nephropathy and a lower proportion of chronic nephritis than female patients ($P < .05$).

3.2. Maturation of AVF

The mean blood flow volume of the brachial artery was 856 ± 370 mL/min at 6 weeks after surgery (minimum 282 mL/min and max 2178 mL/min). There were 50 (69.44%) patients with brachial artery flow exceeding 600 mL/min. The mean diameter of the vein increased to 5.09 ± 0.96 mm 6 weeks after surgery.

Table 1
Demographics and clinical characteristics of the study population.

	All	Gender		<i>t/χ²</i>	<i>P</i> value
		Male	Female		
n	72	26 (36.11)	46 (63.89)		
Age (yr)					
mean ± SD	48.33 ± 13.94	52.92 ± 14.13	45.74 ± 13.29	2.154*	.035
BMI (kg/m ²)					
mean ± SD	21.91 ± 2.60	23.21 ± 2.54	21.18 ± 2.35	3.417*	.001
Hypertension					
No	16 (22.22)	4 (15.38)	12 (26.09)	1.101†	.294
Yes	56 (77.78)	22 (84.62)	34 (73.91)		
Primary disease					
CGN/CKD	42 (58.33)	8 (30.77)	34 (73.91)	18.886†	<.001
DN/DKD	18 (25.00)	14 (53.85)	4 (8.70)		
Other	12 (16.67)	4 (15.38)	8 (17.39)		
Dialysis					
No	36 (50.00)	10 (38.46)	26 (56.52)	2.167†	.141
Yes	36 (50.00)	16 (61.54)	20 (43.48)		
Vein diameter (mm)					
mean ± SD	1.29 ± 0.41	1.32 ± 0.37	1.27 ± 0.43	0.490*	.626
Dilated vein diameter (mm)					
mean ± SD	1.89 ± 0.66	1.95 ± 0.72	1.85 ± 0.62	0.656*	.514
Vein dilation (0 w)					
mean ± SD	1.51 ± 0.37	1.49 ± 0.32	1.51 ± 0.40	0.283*	.778

CGN=chronic glomerulonephritis, CKD=chronic kidney disease, DKD=diabetic kidney disease, DN=diabetic nephropathy, SD=standard deviation.

* the independent-samples *t* test.

† Pearson Chi-square test.

There were 38 (52.78%) patients with a diameter greater than 5 mm. According to the standards mentioned above, the fistulas matured in 32 patients 6 weeks after creation. The maturation rate was 44.44% with 95% CI (32.97%, 55.92%) (Table 2). In the 40 patients whose fistulas failed to mature, 22 patients underwent cuff catheter implantation because they needed hemodialysis in the short term, 8 patients underwent a new arteriovenous fistula anastomosis in a proximal position, 3 underwent artificial vascular fistula anastomosis, three underwent balloon dilatation, and another 4 patients obtained mature fistulas after a longer period of observation.

3.3. Univariate analysis

Patients with fistula maturation exhibited significantly higher hemoglobin levels than those with fistula nonmaturation ($P < .05$). Patients with fistula maturation exhibited significantly higher systolic blood pressure (SBP), cephalic vein dilation (0

week), and cephalic vein dilation (6 weeks) compared with patients with fistula nonmaturation ($P < .05$) (Table 3).

3.4. Multivariate logistic regression analysis

Multivariate logistic regression analysis was performed to assess the independent association of each parameter with fistula maturation. An initial model (Model 1) provided ORs for fistula maturation based on cephalic vein diameter, adjusting for gender, age, BMI, hypertension, hemoglobin, dialysis and primary disease. To account for the influence of vein dilation on fistula maturation, cephalic vein diameter was replaced by cephalic vein dilation (0 week) in Model 2. Model 3 included covariates in Model 1 plus cephalic vein dilation (0 week). Multivariate logistic regression analysis revealed a significant relationship between fistula maturation and cephalic vein dilation (0 week) (OR = 33.975, $P = .010$) as well as cephalic vein dilation (6 w) (OR = 2.586, $P = .042$). This analysis revealed no relationship between fistula maturation and other clinical variables, including gender, age, BMI, hypertension, hemoglobin, dialysis, primary disease and cephalic vein diameter (Tables 4 and 5).

3.5. ROC analysis of the vein dilation (0 week) and the combined index

3.5.1. Comparisons between the training data set and testing data set. There were 58 patients in the training data set (80.56%) and 14 patients in the testing data set (19.44%). There were no significant differences in the means of hemoglobin or vein dilation (0 week) between the 2 data sets ($P > .05$). There were also no significant differences in the composition of gender and primary disease between the 2 datasets ($P > .05$). The fistula maturation rate was 43.10% in the training data set and 50.00%

Table 2
Maturation of AVF in this group.

	n (%)
Blood flow volume of brachial artery (6 w), (mL/min)	
<600	22 (30.56)
≥600	50 (69.44)
Postoperative vein diameter (6 w), (mm)	
<5	34 (47.22)
≥5	38 (52.78)
Mature	
No	40 (55.56)
Yes	32 (44.44)

Table 3**Univariate analysis of factors influencing fistula maturation.**

		All	Mature		<i>t</i> / χ^2	<i>P</i> value
		No	Yes			
n		72	40 (55.56)	32 (44.44)		
Gender	Male	26	12 (46.15)	14 (53.85)	1.457*	.227
	Female	46	28 (60.87)	18 (39.13)		
Age (years)	mean \pm SD	48.33 \pm 13.94	49.35 \pm 13.98	47.06 \pm 14.01	0.689 [†]	.493
BMI (kg/m ²)	mean \pm SD	21.91 \pm 2.60	21.98 \pm 2.41	21.82 \pm 2.84	0.257 [†]	.798
Primary disease	CGN/CKD	42	20 (47.62)	22 (52.38)	2.571*	.276
	DN/DKD	18	12 (66.67)	6 (33.33)		
	Other	12	8 (66.67)	4 (33.33)		
Dialysis	No	36	22 (61.11)	14 (38.89)	0.900*	.343
	Yes	36	18 (50.00)	18 (50.00)		
SBP (mmHg)	mean \pm SD	148.22 \pm 14.77	144.95 \pm 14.25	152.31 \pm 14.61	2.154 [†]	.035
DBP (mmHg)	mean \pm SD	88.81 \pm 15.09	86.15 \pm 11.43	92.13 \pm 18.34	1.691 [†]	.095
Hypertension	No	16	12 (75.00)	4 (25.00)	3.150*	.076
	Yes	56	28 (50.00)	28 (50.00)		
Diameter of anastomotic (mm)	mean \pm SD	8.50 \pm 1.10	8.50 \pm 1.09	8.50 \pm 1.14	0.000 [†]	1
Hemoglobin (g/L)	mean \pm SD	83.36 \pm 19.43	77.95 \pm 11.00	90.13 \pm 25.05	2.762 [†]	.007
Vein diameter (mm)	mean \pm SD	1.29 \pm 0.41	1.37 \pm 0.37	1.20 \pm 0.44	1.735 [†]	.087
Dilated vein diameter (mm)	mean \pm SD	1.89 \pm 0.66	1.87 \pm 0.54	1.91 \pm 0.79	0.232 [†]	.818
Vein dilation (0 w)	mean \pm SD	1.51 \pm 0.37	1.39 \pm 0.23	1.65 \pm 0.46	3.215 [†]	.002
Vein dilation (1 w)	mean \pm SD	2.38 \pm 1.06	2.24 \pm 0.92	2.55 \pm 1.21	1.237 [†]	.220
Vein dilation (2 w)	mean \pm SD	2.57 \pm 1.17	2.38 \pm 1.01	2.81 \pm 1.32	1.555 [†]	.124
Vein dilation (4 w)	mean \pm SD	2.83 \pm 1.30	2.56 \pm 1.02	3.16 \pm 1.54	1.961 [†]	.054
Vein dilation (6 w)	mean \pm SD	3.07 \pm 1.32	2.71 \pm 1.15	3.50 \pm 1.41	2.617 [†]	.011

* Pearson Chi-square test.

[†] the independent-samples *t* test.

CGN=chronic glomerulonephritis, CKD=chronic kidney disease, DBP=diastolic blood pressure, DKD=diabetic kidney disease, DN=diabetic nephropathy, SBP=systolic blood pressure.

in the testing data set, with no significant difference between the 2 groups ($P=.641$) (Table 6).

3.5.2. The optimal cut-off of vein dilation (0 week) determined by ROC analysis. As shown in Figure 1, the area under the curve (AUC) of vein dilation (0 w) and the 95% CI were 0.673 (0.530, 0.816), $P=.025$. The optimal cut-off of vein dilation

(0 week) was 1.31 according to the Youden index maximum method.

3.5.3. The optimal cut-off of combined index determined by ROC analysis. Gender, primary disease, hemoglobin, and vein dilation were the four independent influencing factors for fistula maturation (Table 4, Model 3). The four independent influencing

Table 4**Multivariate logistic regression analysis of factors including preoperative vein dilation influencing fistula maturation.**

	Model 1		Model 2		Model 3	
	OR & 95% CI	<i>P</i> value	OR & 95% CI	<i>P</i> value	OR & 95% CI	<i>P</i> value
Gender						
Male	1		1		1	
Female	0.082 (0.014, 0.468)	.005	0.101 (0.018, 0.552)	.008	0.073 (0.012, 0.433)	.004
Age (yr)	0.997 (0.948, 1.049)	.911	1.003 (0.955, 1.053)	.913	0.999 (0.950, 1.051)	.979
BMI (kg/m ²)	0.958 (0.744, 1.233)	.737	0.935 (0.715, 1.223)	.625	0.911 (0.688, 1.206)	.514
Primary disease						
CGN/CKD	1		1		1	
DN/DKD	0.060 (0.007, 0.492)	.009	0.042 (0.004, 0.417)	.007	0.030 (0.003, 0.305)	.003
Other	0.112 (0.012, 1.066)	.057	0.305 (0.051, 1.838)	.195	0.097 (0.008, 1.179)	.067
Hypertension						
No	1		1		1	
Yes	3.071 (0.667, 14.140)	.150	2.604 (0.530, 12.795)	.239	3.766 (0.666, 21.279)	.133
Dialysis						
No	1		1		1	
Yes	2.094 (0.569, 7.702)	.266	2.847 (0.778, 10.422)	.114	2.117 (0.562, 7.972)	.267
Hemoglobin (g/L)	1.063 (1.017, 1.111)	.007	1.054 (1.012, 1.098)	.012	1.077 (1.021, 1.136)	.007
Vein diameter (mm)	1.557 (0.251, 9.660)	.635			6.059 (0.513, 71.507)	.153
Vein dilation (0 w)			20.224 (1.634, 250.240)	.019	33.975 (2.309, 499.837)	.010

CGN=chronic glomerulonephritis, CKD=chronic kidney disease, DKD=diabetic kidney disease, DN=diabetic nephropathy, OR=odds ratio.

Table 5
Multivariate logistic regression analysis of factors including postoperative vein dilations influencing fistula maturation.

	1 wk		2 wk		4 wk		6 wk	
	OR & 95% CI	P value	OR & 95% CI	P value	OR & 95% CI	P value	OR & 95% CI	P value
Gender								
Male	1		1		1		1	
Female	0.081 (0.014,0.468)	.005	0.077 (0.013,0.457)	.005	0.070 (0.011,0.444)	.005	0.044 (0.005,0.352)	.003
Age (yr)	0.996 (0.946,1.05)	.894	0.995 (0.945,1.048)	.860	0.992 (0.941,1.047)	.779	0.986 (0.932,1.044)	.638
BMI (kg/m ²)	0.962 (0.738,1.255)	.777	0.990 (0.758,1.294)	.943	0.984 (0.762,1.272)	.904	1.014 (0.784,1.311)	.915
Primary disease								
CGN/CKD	1		1		1		1	
DN/DKD	0.061 (0.007,0.493)	.009	0.060 (0.007,0.493)	.009	0.065 (0.008,0.543)	.012	0.055 (0.006,0.500)	.010
Other	0.110 (0.011,1.071)	.057	0.102 (0.010,1.002)	.050	0.107 (0.011,1.040)	.054	0.091 (0.008,1.062)	.056
Hypertension								
No	1		1		1		1	
Yes	3.005 (0.623,14.501)	.171	2.757 (0.583,13.040)	.201	2.497 (0.525,11.879)	.250	1.924 (0.406,9.120)	.410
Dialysis								
No	1		1		1		1	
Yes	2.110 (0.569,7.827)	.264	2.214 (0.586,8.372)	.241	2.313 (0.602,8.894)	.222	2.857 (0.660,12.376)	.160
Hemoglobin (g/L)	1.063 (1.017,1.110)	.007	1.062 (1.018,1.109)	.005	1.062 (1.018,1.107)	.005	1.065 (1.020,1.111)	.004
Vein diameter (mm)	1.755 (0.104,29.577)	.696	2.829 (0.215,37.216)	.429	3.726 (0.263,52.786)	.331	13.303 (0.746,237.129)	.078
Vein dilation	1.058 (0.384,2.915)	.913	1.313 (0.581,2.967)	.512	1.447 (0.657,3.187)	.359	2.586 (1.037,6.451)	.042

CGN=chronic glomerulonephritis, CKD=chronic kidney disease, DKD=diabetic kidney disease, DN=diabetic nephropathy, OR=odds ratio.

factors were used to establish a combined index using logistic regression analysis in the training data set.

Combined index = 1 / (1 + (EXP(6.319 + 1.583 × (gender = female) + 1.751 × (primary disease = DN/DKD) - 0.038 × hemoglobin - 2.963 × vein dilation (0 week))))).

As shown in Figure 2, the AUC of the combined index and the 95% CI were 0.801 (0.680, 0.922), *P* < .001. The optimal cut-off of the combined index was 0.4733 according to the Youden index maximum method.

3.5.4. Predictive effect of vein dilation (0 week) and the combined index on fistula maturation. In the training and testing data sets, the sensitivity, specificity and Youden index for predicting fistula maturation with vein dilation (0 week) and combined index are shown in Table 7. The fistula maturation rates of the 2 groups divided according to the best cut-off are also shown in Table 7. The fistula maturation rate in patients with vein dilation greater than or equal to the cut-off (1.31) was 54.55% in the validation data set. The fistula maturation rate in

patients with the combined index greater than or equal to the cut-off (0.4733) was 77.78% in the testing data set.

4. Discussion

In general, two variables are required for AVF maturation. First, the AVF should have adequate blood flow to support dialysis; second, it should be of sufficient size to allow for successful repetitive cannulation.^[16] Kidney Disease Outcomes Quality Initiative (K-DOQI) suggested that a mature fistula should be able to support a blood flow of 600 mL/min with a diameter greater than 6 mm.^[17] Some experts also recommended that mature fistula puncture vessels should be 5 mm in diameter.^[18] Given that the patients investigated in this study had small cephalic veins (diameter <2 mm), the definition of a mature fistula was adjusted to a diameter greater than 5 mm.

Normally, increments in blood flow begin to occur soon after AVF construction. Major changes in fistula blood flow and size occurred within four weeks after fistula construction. No

Table 6
Comparisons between training data set and testing data set.

		Total	Data set		<i>t</i> / χ^2	<i>P</i> value
			Training data set	Testing data set		
n		72	58 (80.56)	14 (19.44)		
Gender	male	26 (36.11)	20 (34.48)	6 (42.86)	0.343*	.558
	female	46 (63.89)	38 (65.52)	8 (57.14)		
Primary disease	else	54 (75.00)	45 (77.59)	9 (64.29)	1.064*	.302
	DN/DKD	18 (25.00)	13 (22.41)	5 (35.71)		
Hemoglobin (g/L)	mean ± SD	83.36 ± 19.43	83.00 ± 20.31	84.86 ± 15.82	0.319†	.751
Vein dilation (0 wk)	mean ± SD	1.51 ± 0.37	1.48 ± 0.36	1.61 ± 0.43	1.176†	.244
Mature	no	40 (55.56)	33 (56.90)	7 (50.00)	0.217*	.641
	yes	32 (44.44)	25 (43.10)	7 (50.00)		

* Pearson Chi-square test.

† the independent-samples *t* test.

DN=diabetic nephropathy, DKD=diabetic kidney disease.

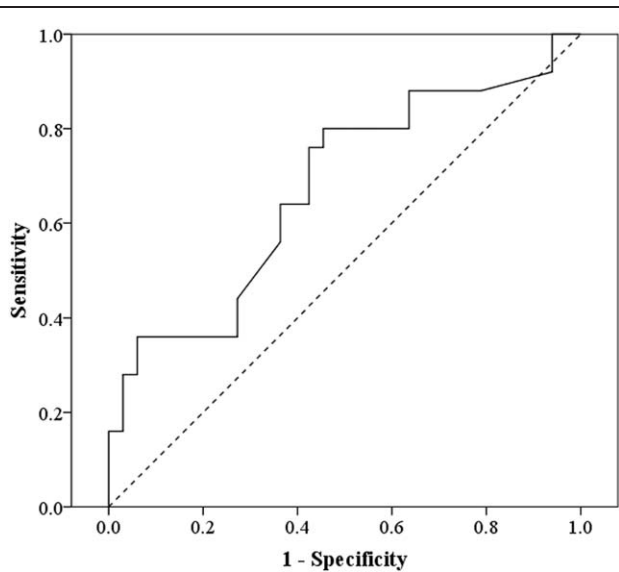


Figure 1. ROC curve by vein dilation (0 w).

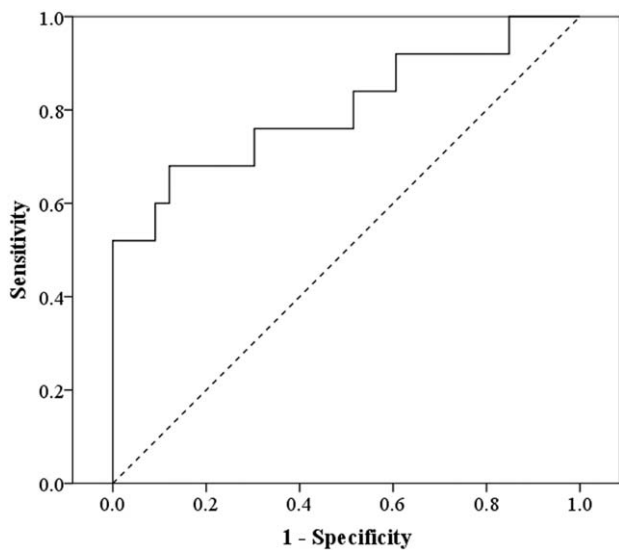


Figure 2. ROC curve by combined index established by independent influencing factors for fistula maturation.

significant changes in these two parameters were noted in the second, third or fourth month after fistula creation.^[19–21] Maloyrh noted that good medical practice would suggest that

a fistula should be evaluated for developmental adequacy within 4 to 6 weeks.^[22] Therefore, the patients were followed up for 6 weeks after surgery in this study. The maturation rate of AVF 6 weeks after surgery in this cohort was 44.44%, which is slightly lower than that reported in other studies.^[4,23] A potential reason is that the cephalic vein diameter in the patients enrolled in this study was significantly smaller than those reported in other studies.

Various studies have documented that patients with a larger minimum vein diameter on preoperative vein mapping are at lower risk for failure of fistula maturation and exhibit greater long-term AVF patency.^[10] Some experts suggest a vein diameter of 2.0 mm as adequate for AVF creation.^[5] The preferred minimal vein diameter after dilation for RCAVF creation is 2.5 mm.^[11,12] Japanese experts suggest that 1.6 to 2.5 mm is a suitable dilated vein diameter range for AVF creation.^[8] However, our study revealed no relationship between fistula maturation and cephalic vein diameter (dilated or not). The result remained unchanged after adjustment for gender, age, BMI, hypertension, hemoglobin, dialysis, and primary disease. These findings suggest that cephalic vein diameter may not be an independent risk factor for AVF maturation in patients with very small cephalic veins. In this case, it is essential to evaluate whether cephalic vein dilation affects AVF maturation. We measured cephalic vein dilation preoperatively and at 1, 2, 4, and 6 weeks after surgery. Preoperative venous dilation was associated with AVF maturation. The greater the cephalic vein dilation was, the greater the likelihood of AVF maturation. After eliminating the influence of venous diameter, preoperative vein dilation still significantly affected AVF maturation (OR=33.975, $P=.010$). This result suggests that preoperative venous dilation is an independent factor affecting fistula maturation. The dilation of the cephalic vein at 1, 2, and 4 weeks after operation were not related to AVF maturation (data shown in Table 5). Despite the fact that vein dilation at 6 weeks after surgery exhibited a significant relationship with fistula maturation, this has minimal clinical significance because it cannot play an early role in assessing AVF maturation.

The most important mechanism of AVF maturation, however, is likely to be the response of the draining vein to the increase in shear stress that occurs after the creation of an arteriovenous anastomosis.^[24] An increase in blood flow and consequent shear stress after the creation of an AVF will result in attempts to decrease the shear stress applied to the vessel wall.^[25] Given that blood viscosity is difficult to alter, an increase in shear stress invariably results in vascular dilation. Although the veins in this group were small, there remains an opportunity for AVF surgery and maturation as long as sufficient dilation ability is observed. Our results suggest that, for patients with very small veins,

Table 7
Predictive effect of vein dilation (0 w) and combined index on fistula maturation.

Data set	Evaluation indexes (%)			Mature (%)		
	Sensitivity	Specificity	Youden index	≥Cut-off	<Cut-off	
Vein dilation (0 w)*	Training data set	80.00	54.55	34.55	57.14	21.74
	Testing data set	85.71	28.57	14.29	54.55	33.33
Combined index†	Training data set	68.00	87.88	55.88	80.95	21.62
	Testing data set	87.50	66.67	54.17	77.78	20.00

* The best cut-off of vein dilation (0 w) is 1.31.

† The combined index is established by logistic regression analysis using the four independent influencing factors for fistula maturation (gender, primary disease, hemoglobin, and vein dilation). The best cut-off of the combined index is 0.4733.

venous dilatability must be carefully assessed before surgery, as it may be a better predictor of AVF maturation than venous diameter (dilated or not). For patients with good dilatability, AVF is still recommended with a high maturation rate.

5. Limitation

To explore the cut-off of vein dilation, 72 samples were randomly divided into a training data set and a testing data set. ROC analysis was used to determine the optimal cut-off of vein dilation with the Youden index maximum method. The independent predictive indicators for fistula maturation were used to establish a combined index, the cut-off of which was also studied. The study of the cut-off of vein dilation and the combined index helped us to determine the amount of distensibility predicting successful maturation and the decision as to whether a small vein should be abandoned for arteriovenous anastomosis. However, considering the small sample size ($n = 72$) of this study, we did not report the extent to which vein dilation improves the fistula maturation rate. Further studies with larger patient cohorts are required to determine the optimal cut-off for vein dilation applicable to clinical practice.

Author contributions

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